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LOW SPEED WIND TUNNEL FLOW FIELD RESULTS  
FOR JT8D REFAN ENGINES ON THE BOEING 727-200

by W. G. Easterbrook and W. H. Roberts

BOEING COMMERCIAL AIRPLANE COMPANY  
A DIVISION OF  
THE BOEING COMPANY

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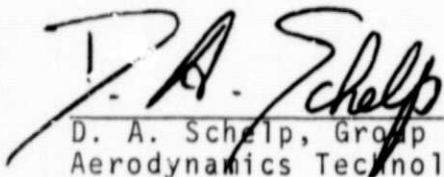
(NASA-CR-134630) LOW SPEED WIND TUNNEL  
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# FOREWORD

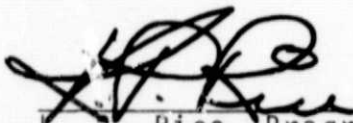
The low speed wind tunnel testing described in this report was conducted by the Aerodynamics Technology Staff of the Boeing Commercial Airplane Company, a division of The Boeing Company, Seattle, Washington. This work was sponsored by NASA Lewis Research Center and was performed between May 1973 and March 1974.

  
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## 1.0 SUMMARY

Flow field angularity was measured at aft fuselage engine locations on the Boeing 727-200 during a low speed test of JT8D Refan engine configurations. The test was conducted at the Boeing Vertol Wind Tunnel at Morton, Pennsylvania. Flow angles were measured at nacelle inlet highlight positions for the side and center engines. Two flow angle probes (yaw heads) were mounted at each inlet position. Angle measurements were obtained for airplane flap settings of  $0^{\circ}$ ,  $15^{\circ}$ , and  $40^{\circ}$  so the full range of flap angles were investigated. The following results were obtained:

- o The magnitude of the down-flow angle decreased with increasing wing angle of attack up to the attitude for stall. Thus, the smallest down-flow angle occurred just prior to stall.
- o High values of down-flow angle were measured just beyond the stall attitude, and, as angle of attack was increased further, wide fluctuations in angle resulted.
- o Down-flow angles at the center inlet location were always lower in magnitude than those measured at the side nacelle location. Angle differences at the two different locations became greater at higher flap settings.
- o Cross-flow angles at the side nacelle location were in a direction toward the body (as could be expected because of body closure) for angles of attack up to stall. Small cross-flow angles were indicated at the center inlet location but these must be considered as data scatter.

## 2.0 INTRODUCTION

The Pratt & Whitney Aircraft refan engine (designated JT8D-109) is a derivative of the JT8D-9 turbofan engine. A larger diameter, single-stage fan has been incorporated which raises the bypass ratio to 2.03. The intent of this engine modification is to provide lower jet noise, increased takeoff and cruise thrust, and lower specific fuel consumption. Larger side engine nacelles and a larger center inlet must be provided if the JT8D-109 engine is to be installed on the Boeing 727-200 airplane. The affected regions are indicated on the 727 general arrangement shown on Figure 1.

Flow angle testing was initiated in support of Propulsion Staff testing of internal inlet characteristics. The range of anticipated flow angles at the side nacelle inlets and at the center inlet was required to ensure that the proper range of angles were run during isolated inlet testing.

The flow angle testing was run at the Boeing Vertol Wind Tunnel during May 28 to June 5, 1973. This tunnel has a square test section area of 20 ft. by 20 ft. The model was mounted on a sting support with a dog-leg extension as shown by Figure 2.

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### 3.0 NOMENCLATURE

|            |   |
|------------|---|
| $\gamma_B$ | Down-flow angle relative to the fuselage reference axis, in degrees (+ angle is downward flow relative to the fuselage) |
| $\beta_B$  | Cross-flow angle relative to the fuselage reference axis, in degrees (+ angle is flow inboard toward the fuselage)      |
| $\alpha_W$ | Wing angle of attack with wing design chord plane as reference, in degrees (+ angle is airplane nose-up)                |
| B.S.       | Body Station  |
| W.L.       | Water Line  |
| B.L.       | Buttock Line  |
| BVWT       | Boeing Vertol Wind Tunnel   |

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## 4.0 MODEL AND TEST DESCRIPTION

### 4.1 Model Description

The wind tunnel model used for this flow angle testing was an existing .075 scale model of the Boeing 727-200 airplane. The model configuration included standard 727 wing, fuselage, tail surfaces, flaps, slats, etc. The center inlet and side nacelles were removed to allow the flow angle probes to be placed at inlet highlight locations. The general model configuration with nacelles in place is pictured on Figure 2.

Flow angle probes consisted of hemispherical yaw heads as shown by the sketches of Figure 3. Probe orientation was parallel to the fuselage reference axis. Down-flow and cross-flow angles were therefore measured relative to the fuselage axis. The installation is pictured on the model of Figure 4.

### 4.2 Model Installation and Test Facility

The 727-200 low speed model was sting mounted with a dog-leg sting as pictured on Figure 2. This type of sting was utilized during this test period for other testing which included ground plane work where the additional angle was required. This arrangement was satisfactory for the flow angle testing so the same test arrangement was used. The Boeing Vertol Wind Tunnel facility has a 20 ft. by 20 ft. test section. A few checks of flow angles in ground effect were made to ensure that all reasonable flight conditions were considered.

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#### 4.3 Test Procedure

Individual pressure port measurements were made for the various ports on the probes. A range of wing angles of attack were set and pressure measurements recorded. A data reduction computer program converted these pressures into flow angles, using previous individual probe calibrations.

## 5.0 TEST RESULTS AND DISCUSSION

Inlet flow angles which could be expected in flight were required to set the range of angles to be used for Propulsion Technology Staff testing of inlet characteristics. This included the entire flight regime of the airplane. Representative flap angles were selected as  $0^{\circ}$ ,  $15^{\circ}$  and  $40^{\circ}$ . These settings correspond to cruise, takeoff, and landing conditions respectively. A few ground effect runs were made to check flow angles on the ground.

Down-flow angle data are presented on Figures 5, 6, and 7 according to flap position. The higher flap settings tend to produce the greatest down-flow angles. A general trend is evident with down-flow angle decreasing with angle of attack up to the stall attitude. At airplane attitudes beyond stall there are wide fluctuations in flow angle after an initial sharp increase in down-flow. Generally, the down-flow angles for the normal flight regime tend to be fairly small. This indicates that there should be no problem concerning the inlet inflow angles.

There was little change in flow angle due to ground effect as shown by Figures 5 and 8.

Down-flow at the side nacelle position tends to be greater in magnitude than that at the center inlet location. This is a result that could be expected because the body itself tends to straighten the flow at that location.

Cross-flow results are shown on Figures 8, 9, and 10 for the same conditions as for down flow angle. Cross-flow direction at the side nacelle position was toward the body because the local flow follows the body contour (closure). Cross-flow angles were small in magnitude at airplane angles of attack

up to stall. At higher angles of attack, beyond the stall, the flow direction changes abruptly to an outboard direction.

## 6.0 CONCLUSIONS

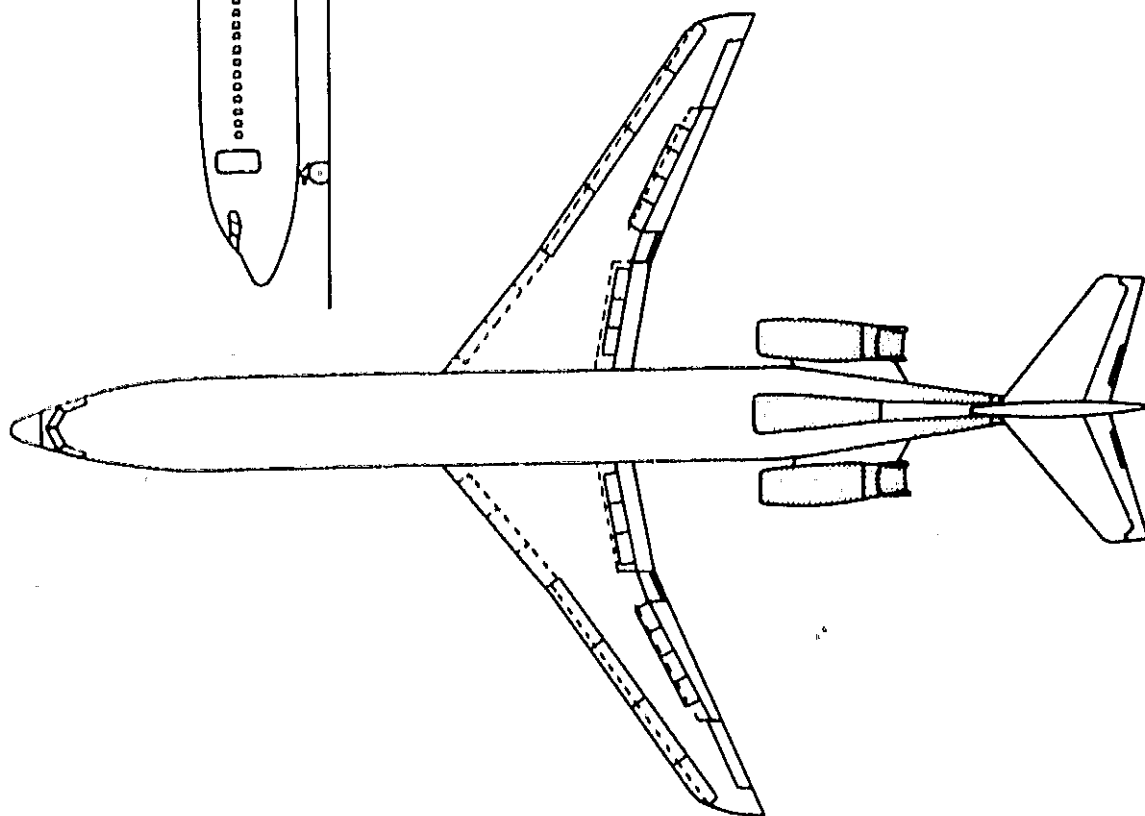
The following conclusions were drawn from the test results:

- Down-flow angles up to stall attitude decreased with increasing angle of attack.
- Down-flow angles at the center inlet location were somewhat lower in magnitude than angles at the side nacelle position. The difference in angle at the two inlet positions became greater at higher flap settings.
- Minimum down-flow angle was obtained just prior to stall.
- High values of down-flow angle were demonstrated just above stall attitude. Flow angle then fluctuated widely for further increases in attitude.
- A general observation was that down-flow angles are relatively small for the normal flight regime of the airplane.
- Cross flow angles were generally small at the side nacelle position at airplane attitudes up to stall. Flow direction was toward the body up to stall angle of attack and then abruptly outboard at post stall attitude.

## 7.0 FIGURES

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AREAS AFFECTED  
BY REFAN ENGINE  
INSTALLATION

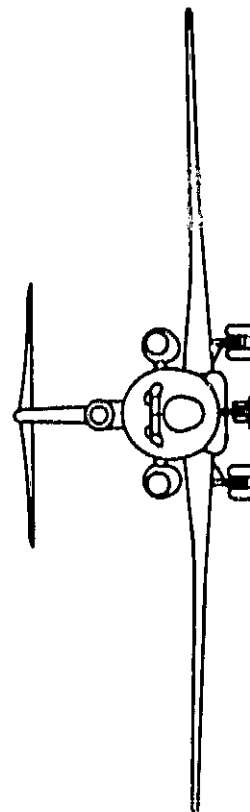
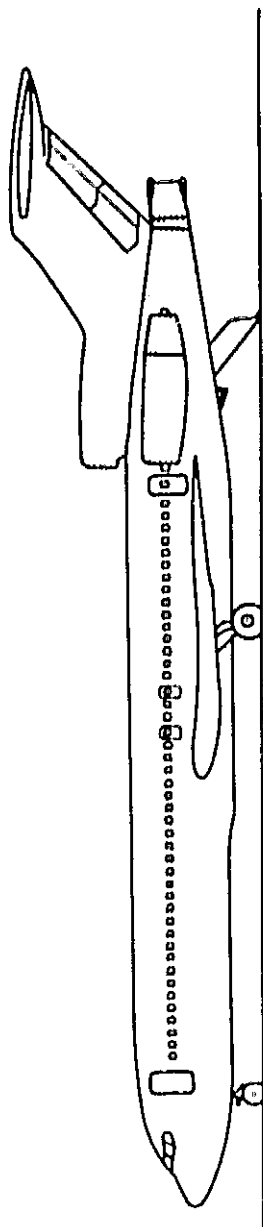


FIGURE 1.-727-200/JT8D-109 REFAN AIRPLANE

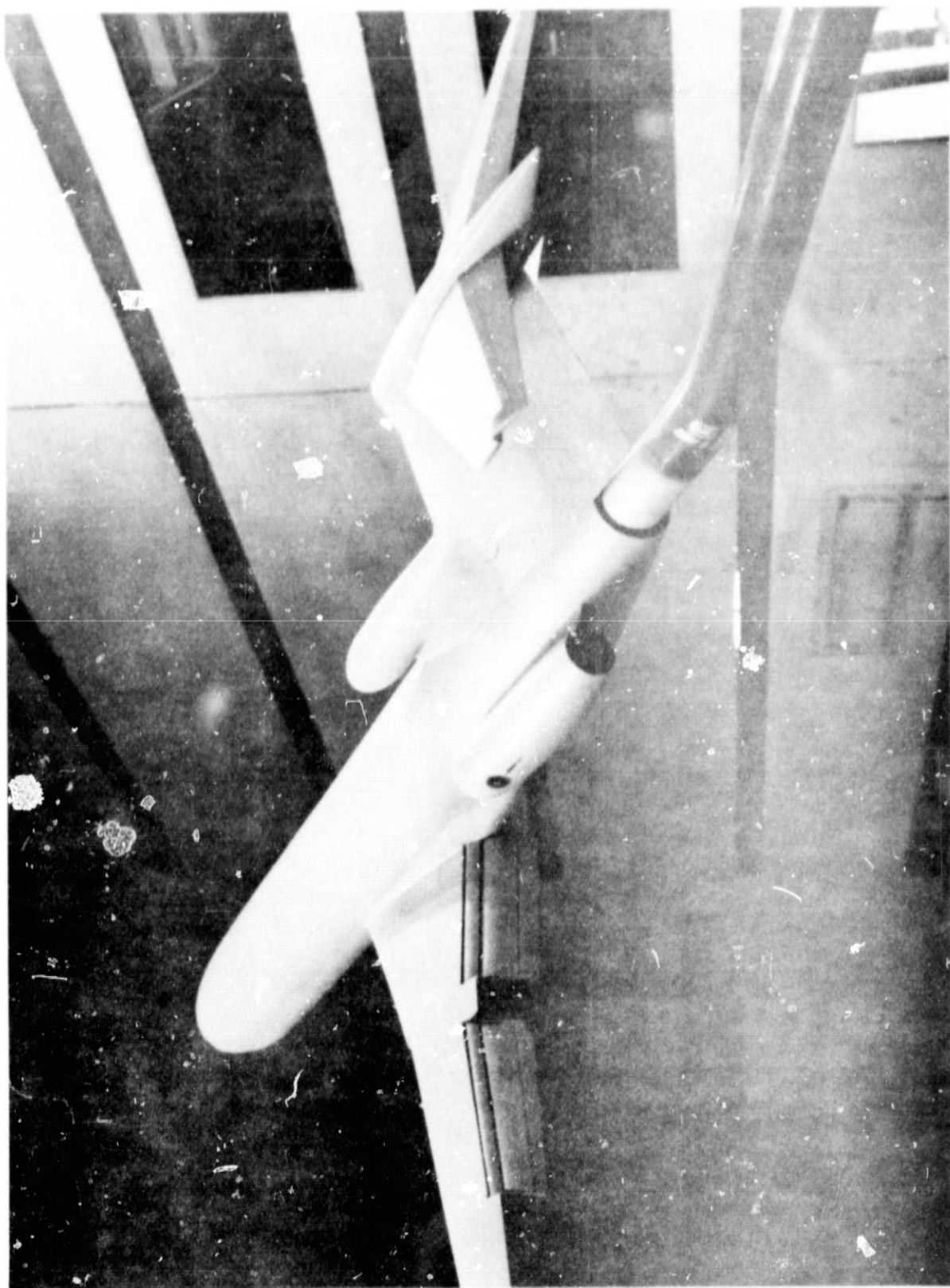


FIGURE 2 - MODEL INSTALLATION

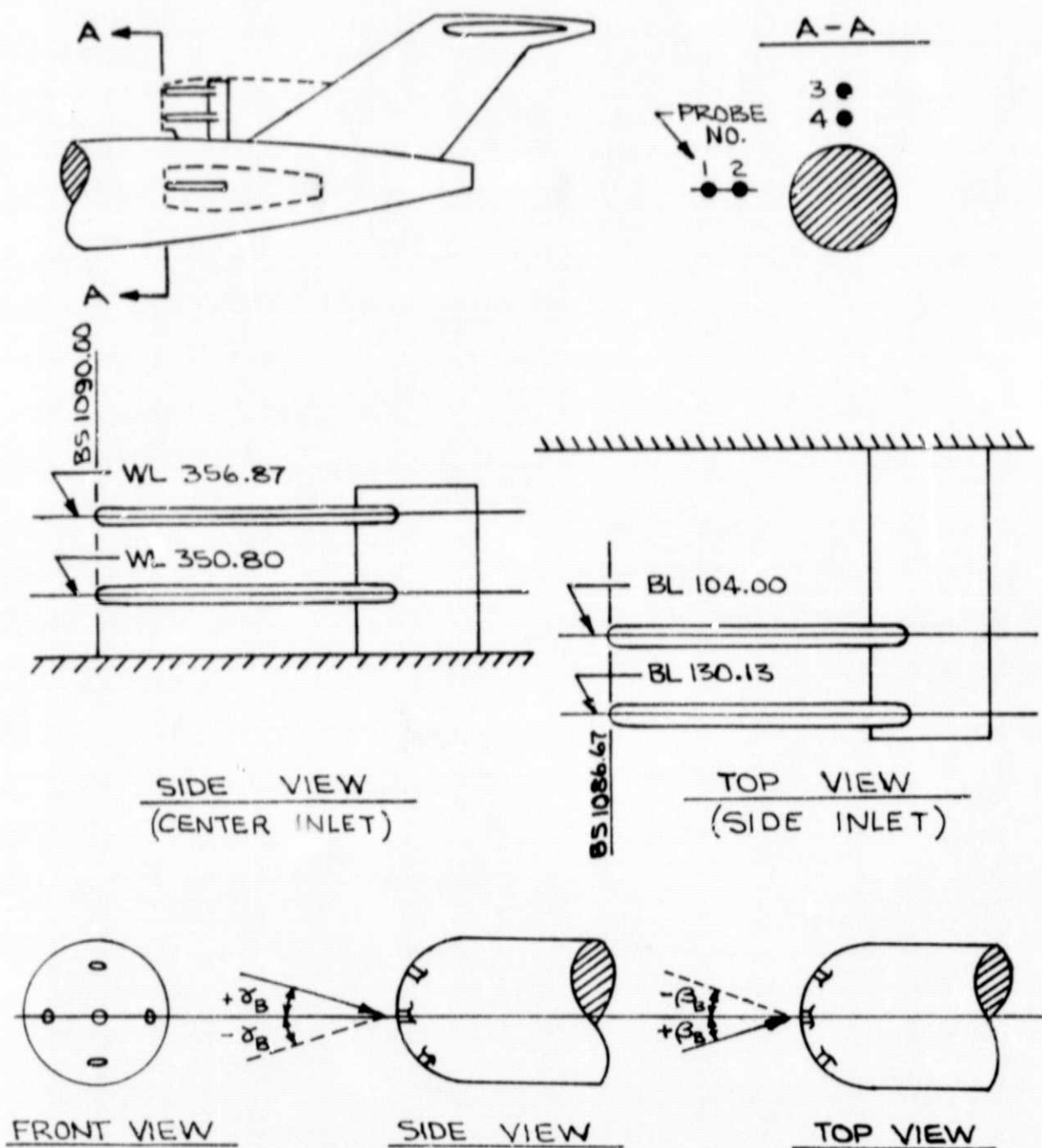


FIGURE 3 - FLOW ANGLE PROBE DETAILS



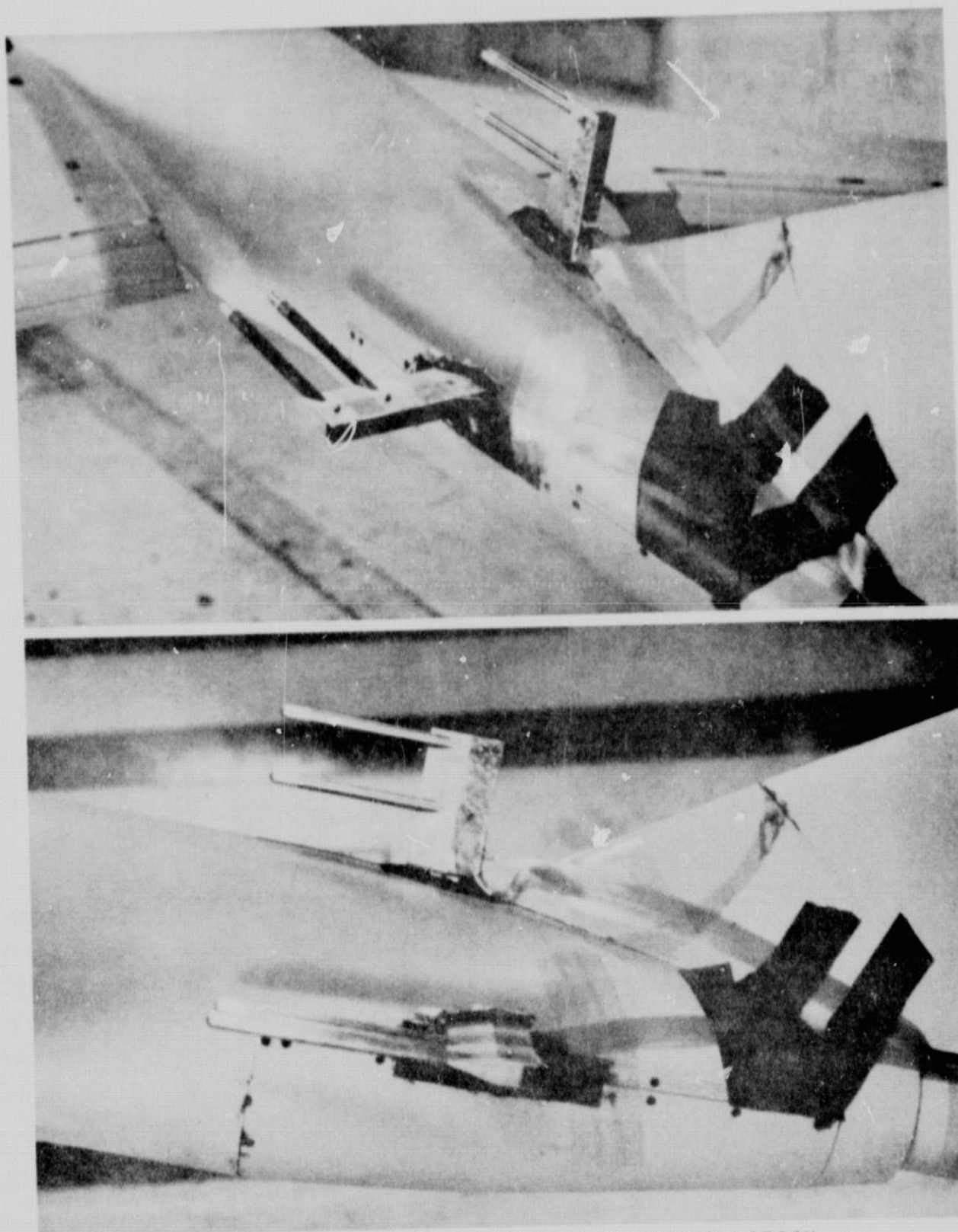


FIGURE 4 - FLOW ANGLE PROBE INSTALLATION

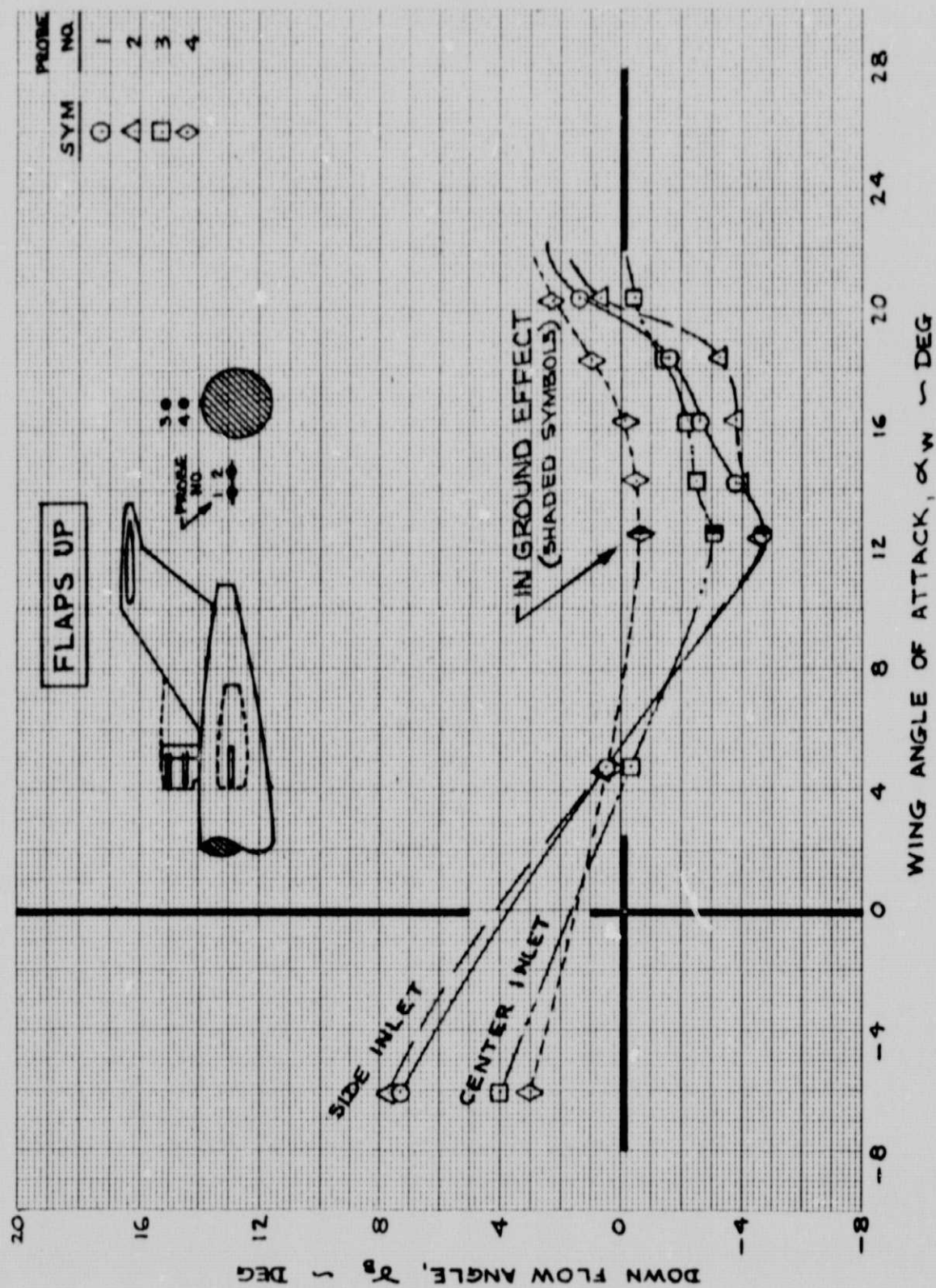


FIGURE 5 - DOWN FLOW ANGLE, FLAPS UP

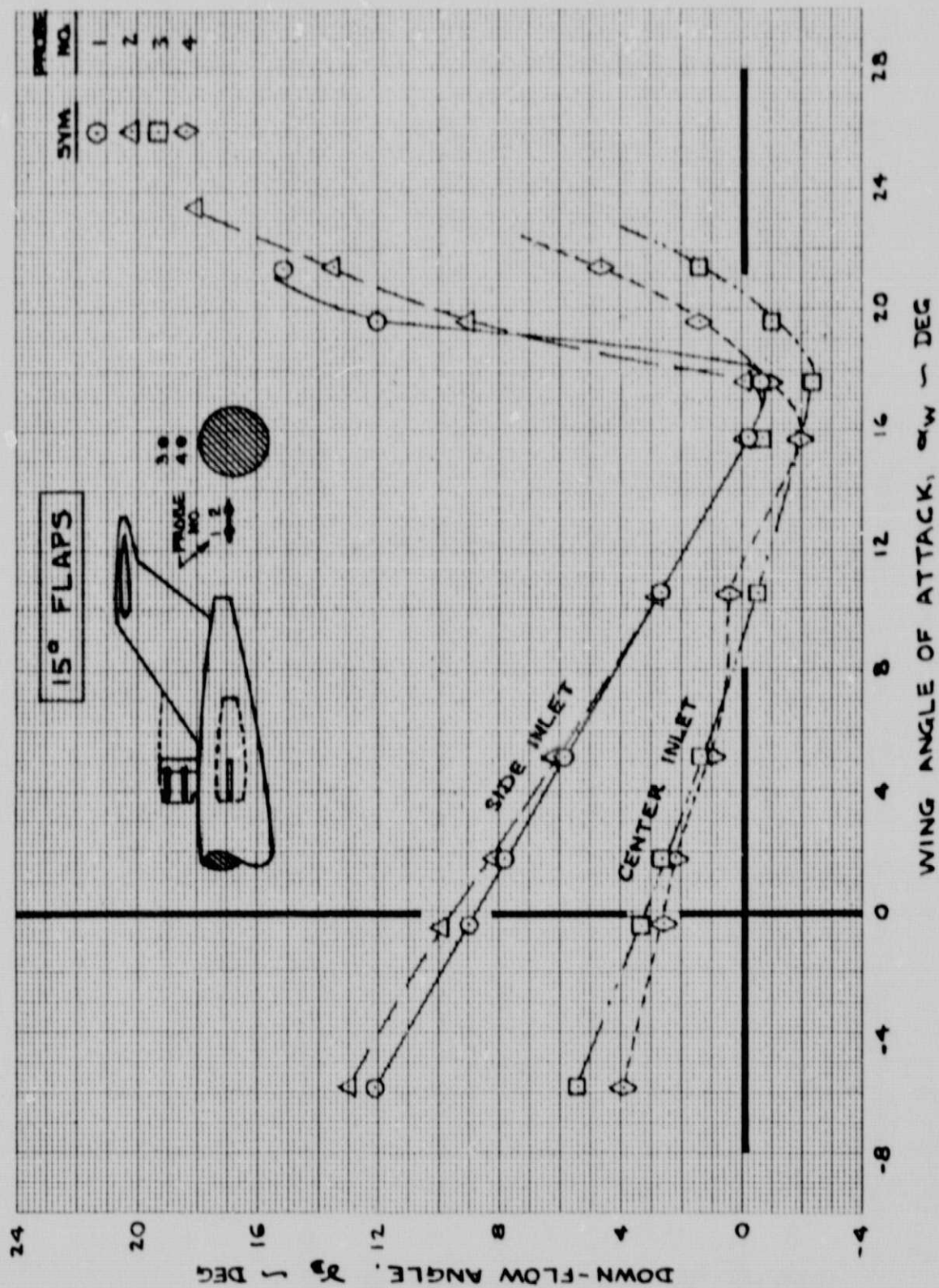
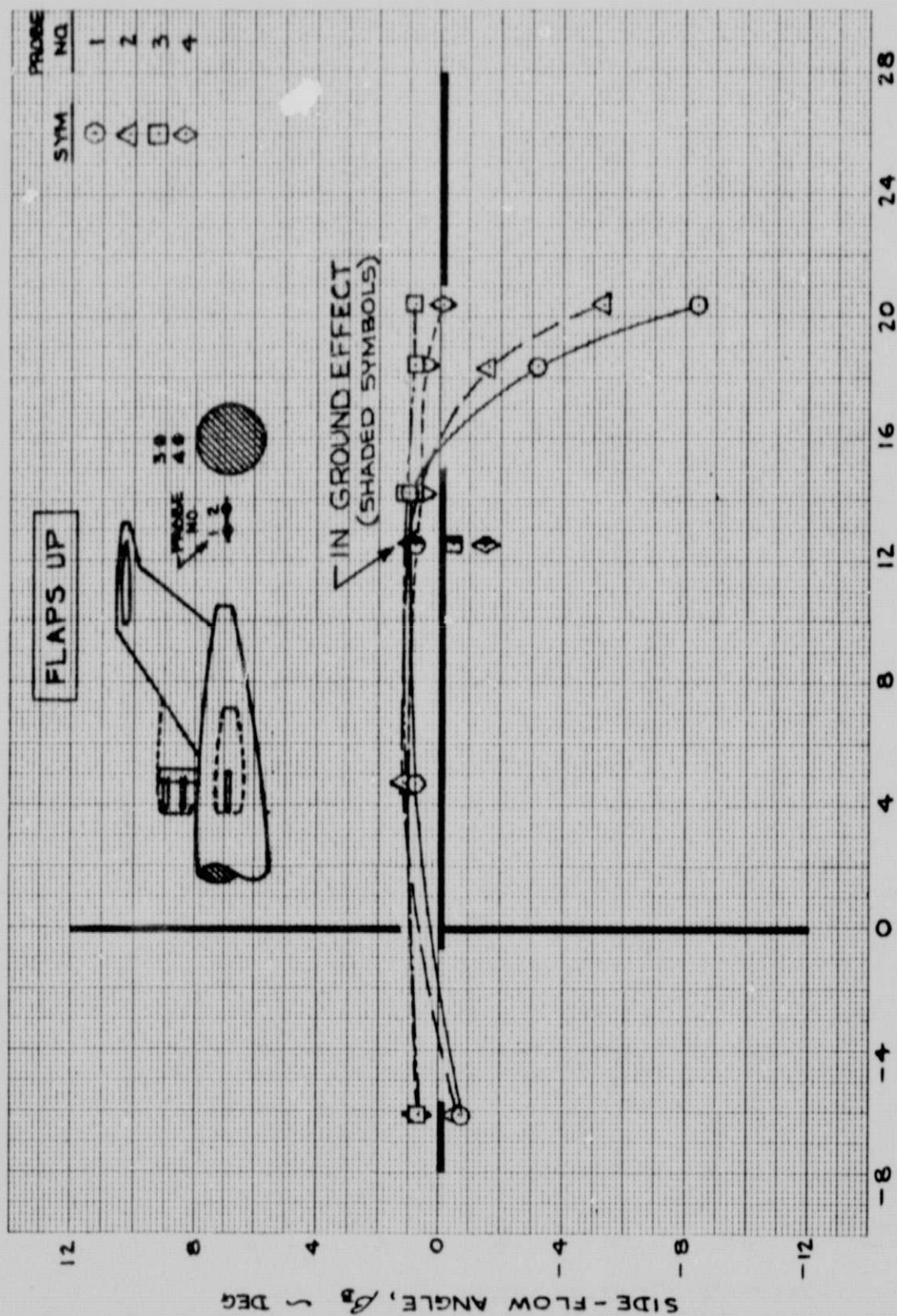


FIGURE 6 - DOWN FLOW ANGLE, FLAPS 15°

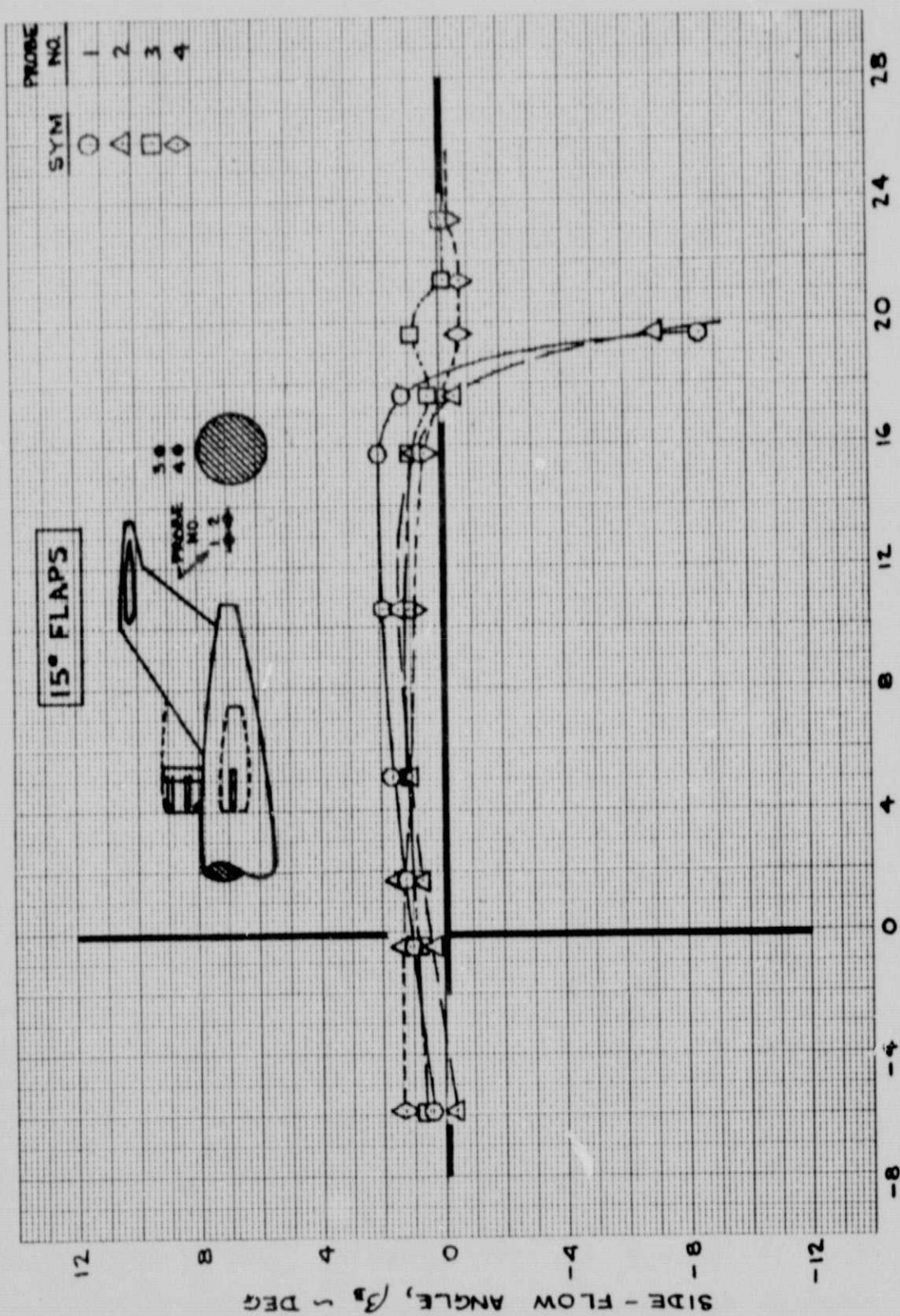






WING ANGLE OF ATTACK,  $\alpha_w$  ~ DEG

FIGURE 3 - SIDE FLOW ANGLE, FLAPS UP



WING ANGLE OF ATTACK,  $\alpha_w$  ~ DEG

FIGURE 9 - SIDE FLOW ANGLE, FLAPS 15°

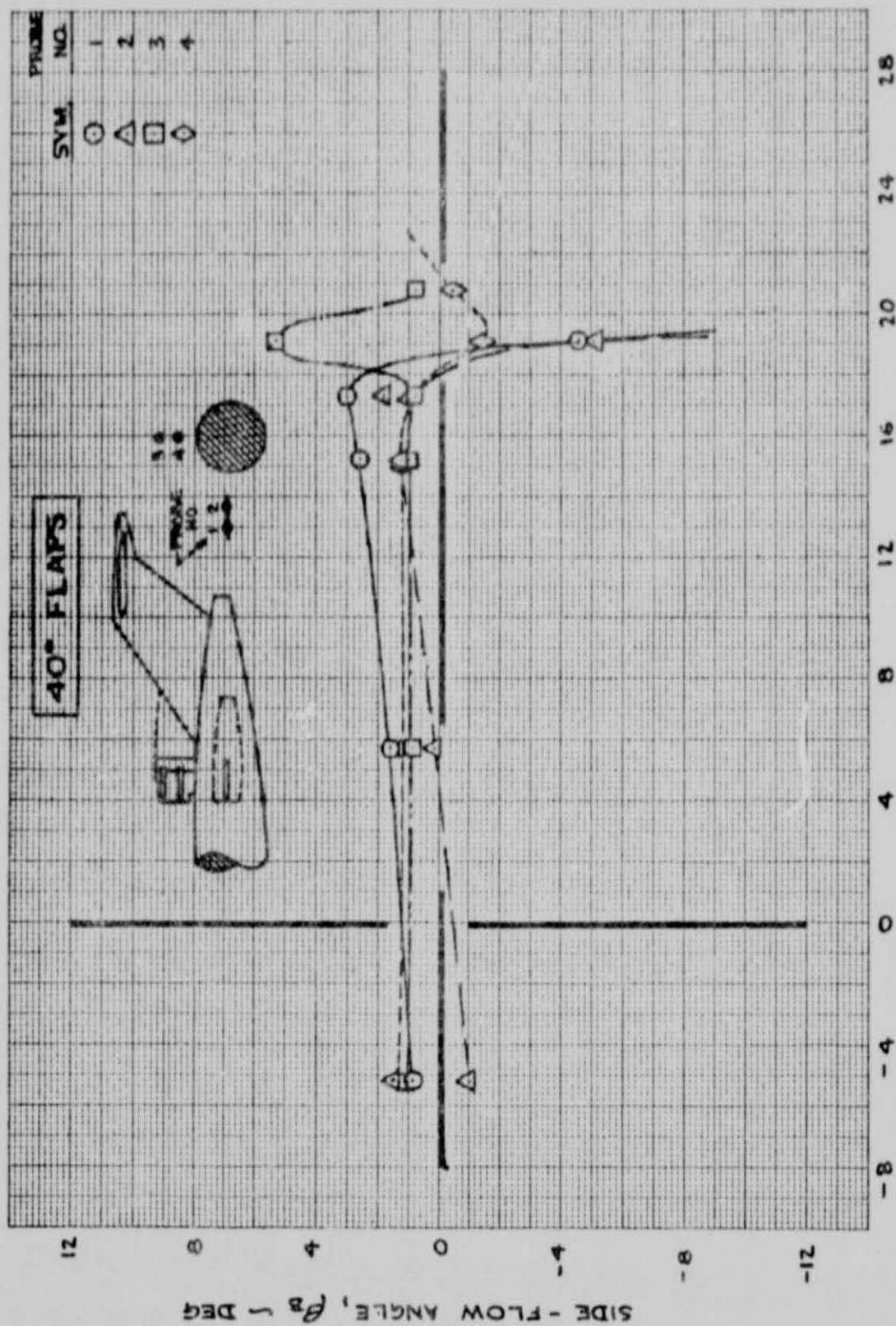


FIGURE 10 - SIDE FLOW ANGLE, FLAPS 40°